

# **DEVELOPMENT OF INBREDS, HYBRIDS, AND ENHANCED GEM BREEDING POPULATIONS WITH SUPERIOR SILAGE YIELD AND NUTRITIONAL VALUE**

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## **Overview:**

Close to 8% of the 31 million hectares of corn harvested in the U.S. were dedicated to silage in 2006 (USDA, 2007). Wisconsin is the major silage-producing state in the U.S. with close to half a million hectares of silage harvested in 2005, representing approximately 25% of the total number of corn hectares harvested in the state that year (WASS, 2006). In areas of the Northeast U.S., silage can occupy up to 50% of the corn production area.

In the early 1990's, motivated by the realization of the substantial economic and nutritional benefits of improving forage quality, primarily corn for silage, the University of Wisconsin (UW) Corn Silage Breeding Program was initiated to enhance both nutritional value and forage yield of corn. This was the first corn silage breeding program in the U.S. focused on the development of corn varieties for biomass production, currently used for animal feed and this program remains the only public program of its kind in the country. The UW Silage Breeding Program has been incorporating new sources of germplasm from the GEM project for a number of years as a means to enhance primarily forage yield but also compositional quality.

The biomass quality properties of corn required for animal nutrition have been found to be parallel to the desired traits to be selected for corn to be used as a feedstock for energy bioconversion. Therefore, the high forage yield and highly fermentable cell wall carbohydrate composition of the populations and crosses involving germplasm developed by the UW Corn Silage Breeding Program have shown promise for developing ligno-cellulosic biofeedstocks for ethanol production.

In 2007, The UW Corn Silage Breeding Program continued to evaluate silage yield and nutritive value of the most productive GEM crosses identified in grain yield evaluations conducted over the past several years by the GEM project. These hybrids are chosen annually based on maturity and excellent grain yield in GEM evaluations conducted in previous years throughout the U.S. Corn Belt. If any of these crosses have high dry matter yield and good nutritional quality in our UW trials, the respective GEM parent or breeding population is included in the UW inbred development nursery for further inbreeding and selection. The 2007 trials focused primarily of the advanced-generation inbred testing of GEM materials.

## **2007 Field Trials:**

Three trials involving GEM materials (BR52051, CUBA164 and GEM244) were planted in 2007 at two WI locations, Madison (May 7) and Arlington (May 21). Trials were planted in triplicates in each of the locations with an average planting density of 32,800 plants/acre. Severe drought conditions affected both locations during the month of July which caused some decrease in average yields primarily in

Madison and some lodging in both locations. Lodging scores were recorded at both locations for all trials. The Madison trials were harvested in early-September. The Arlington trials were harvested in mid-September. For a detailed description of these trials please see <http://cornbreeding.wisc.edu>.

## **BR52051**

Trial **BR52051** consisted of the silage evaluation of advanced inbred lines from the GEM program derived from BR52051:N04-68-1-B-B, BR52051:N04-68-1-B-B, BR52051:N04-76-1-B-B, SCRO1:N1310-398-1-B and CHO5015:N15-8-1-B-B. Trial BR52051 included 39 inbreds each crossed to Holdens testers LH244 and LH332, and six hybrid checks (Table 1).

**BR52051 highlights (Table 1):** Of the 39 hybrids evaluated, the forage yield of 16 of those exceeded the highest yielding check (9.89 tons/acre). Of these 16 highest yielding hybrids, only one presented dry matter content below the acceptable threshold for southern Wisconsin environments (> 35%). For 12 of these 16 hybrids, lodging scores were below the trial average. Lines derived from SCRO1:N1310-398-1-B populations crossed by testers LH244 and LH332 were amongst the highest-yielding hybrids of the trial with yields that exceeded the average trial yield by 6 to 18%. Quality evaluation will be performed for 30 of the 39 hybrids evaluated for yield. It is worthwhile noting that the highest yielding check of this trial was W605S x LH332. Inbred W605S was released by the UW Corn Silage Breeding program in 2004 and was developed from the GEM breeding population AR17026:N1019. Some of the GEM inbred lines evaluated in this trial have also performed well in past years and one or more may be released in the near future.

## **CUBA164**

Trial **CUBA164** consisted of the silage evaluation of advanced inbred lines from the GEM program derived from CHIS775:S1911b-645-1-B-B, CUBA164:S2012-235-1-B, CUBA164:S2012-459-1-B and CUBA164:S2012-966-1-B. Trial CUBA164 included 24 inbreds each crossed to LH279 and LH287 and in some instances by W604S, a high-quality inbred developed by our silage program. This trial also included six hybrid checks (Table 2).

**CUBA164 highlights (Table 2):** Of the 24 hybrids evaluated, the forage yield of 10 of those exceeded the average of the checks, excluding F2F633(bm3). Maturity appears to be an issue with some of these hybrids. The percentage dry matter content of the 10 high yielding hybrids ranged from 31.2 to 38.6% with only three of them being above the check average, excluding F2F633(bm3). The lodging scores were below the trial average for 9 of the 10 high-yielding hybrids. Quality evaluation will be performed for 15 of the 24 hybrids evaluated for yield in this trial.

## **GEM244**

Trial **GEM244** included hybrids involving advanced inbred lines from the GEM program (AR17056:N2025-508-1-B-B-B-B, DK212T:N11a12-122-1-B-B, FS8B(T):N11a-322-1-B-B, SCRO1:N1310-398-1-B and CHO5015:N15-8-1-B-B) each crossed to Holdens tester LH244, along with six check hybrids (Table 3).

**GEM244 highlights (Table 3):** Of the 39 hybrids evaluated, the forage yield of 21 of those exceeded the average of the checks, excluding F2F633(bm3) and 6 of them exceeded the highest-yielding check

(10.8 tons/acre) for this trial. Dry matter contents were above 35% for all 6 highest yielding hybrids and only 1 of the 21 hybrids was below the 35% dry matter content acceptable for southern Wisconsin environments. The average lodging score for the checks in this trial was quite high, but only 5 of the 21 high-yielding hybrids had lodging scores higher than the trial average. Lines derived from FS8B(T):N11a-322-1-B-B populations crossed by Holdens tester LH244 were amongst the highest yielding hybrids of the trial with yields that exceeded the average yield for this trial by 12 to 19%. Quality evaluation will be performed for 22 of the 39 hybrids evaluated for yield. Once again, some of the GEM inbred lines included in this trial look very promising because they have also performed well in past years. Therefore, one or more of these lines may be released in the future.

Nutritional evaluations are not yet completed. Nutritional evaluations will include assessment of neutral detergent fiber (NDF), in vitro true digestibility (IVD), in vitro NDF digestibility (IVNDFD), crude protein (CP), and starch concentration. Based on these values, milk/ton of forage and milk/acre will be estimated based on MILK2006, which uses forage composition (NDF, IVD, IVNDFD, CP, and starch) to estimate potential milk production per ton of forage. Forage yield is then used to estimate potential milk per acre. Nutritional evaluation will be completed in approximately one month and the results posted on our web site.

### **2007 Nursery Activities:**

In 2005, a new breeding population derived from GEM-derived sources of germplasm was initiated. This population is designated the GEM Quality Synthetic (GQS). GQS is approximately 75% Stiff Stalk. The aim is to create inbred lines from GQS that produce silage hybrids with high forage yield as well as superior nutritional quality when crossed to inbred lines from our non-Stiff Stalk Wisconsin Quality Synthetic (WQS) breeding population. The breeding population GQS will be advanced using a second generation ( $S_2$ ) top-cross selection method. Briefly, inbreds derived from succeeding cycles of improvement are developed and released. Population improvement and inbred development occur simultaneously.  $S_2$  families derived from GQS are initially screened for general agronomic adequacy and are then top-crossed to elite commercial lines from complementary heterotic groups during the following year. The following summer, top-crosses are grown to estimate forage yield and quality of whole-plant compositional characteristics such as fiber, digestibility, protein, and starch at silage harvesting time. Twenty  $S_2$  families are selected based on a performance index (MILK2006) that comprises silage yield and compositional quality. During summer 2007 the top 20 selected families from Cycle 0 (GQS C0) of this population were recombined to give rise to GQS C1.

In addition, approximately 150 GEM families were further inbred, and approximately 50 promising S4+ lines were crossed to inbred testers, LH287, LH244, LH332 and W604S for 2008 evaluations. These lines were derived from breeding crosses AR16026:S1719-052-2-B-B-B, CHO5015:N15-8-1-B-B, CHIS775:S1911b-645-1-B-B, CUBA164:S2012-235-1-B, CUBA164:S2012-459-1-B and CUBA164:S2012-966-1-B. We also added several new GEM inbred bulks to our nursery in 2007 for inbred line development. These were GUAT209:S1308a-135-001-B, GUAT209:S1308a-084-001-B, GUAT209:S1308a-013-001-B and DK888:N11a08a:440-001-B.

All activities of the UW silage and biofeedstock breeding program, including nurseries and yield trials, are available through our web site. For additional information please visit: (<http://cornbreeding.wisc.edu>).

Table 1. Forage yield evaluation for BR52051 trial in 2007. Forage yield and lodging scores (0 = no lodging) were evaluated at Madison and Arlington, WI. Entries marked with “\*” will be analyzed for nutritional quality.

07No.	Entry	Mean			Quality Evaluation
		Dry matter	Yield	Lodge score	
		%	t/a	0-10	
1	BR52051:N04-68-1-B-B-3-1-1 X LH244	39.9	9.18	1.0	*
2	BR52051:N04-68-1-B-B-3-1-1 X LH332	41.1	10.54	0.7	*
3	BR52051:N04-68-1-B-B-6-1 X LH244	40.3	9.56	0.3	*
4	BR52051:N04-68-1-B-B-6-1 X LH332	42.5	9.23	0.7	*
5	BR52051:N04-75-1-B-B-6-1-1 X LH244	33.6	9.86	0.0	*
6	BR52051:N04-75-1-B-B-6-1-1 X LH332	36.4	9.96	0.0	*
7	BR52051:N04-75-1-B-B-6-1-2 X LH244	34.5	10.06	0.0	*
8	BR52051:N04-75-1-B-B-6-1-2 X LH332	35.8	9.78	0.0	*
9	BR52051:N04-75-1-B-B-11-1 X LH244	41.3	9.60	0.0	*
10	BR52051:N04-75-1-B-B-11-1 X LH332	41.7	9.25	0.7	*
11	BR52051:N04-75-1-B-B-12-1-1 X LH244	34.8	9.86	0.2	*
12	BR52051:N04-75-1-B-B-12-1-1 X LH332	35.4	9.94	0.0	*
13	BR52051:N04-75-1-B-B-12-1-2 X LH244	33.3	9.85	0.0	*
14	BR52051:N04-75-1-B-B-12-1-2 X LH332	35.3	9.74	0.0	*
15	BR52051:N04-75-1-B-B-13-1 X LH244	33.6	9.46	0.0	
16	BR52051:N04-75-1-B-B-13-1 X LH332	35.6	9.42	0.0	
17	BR52051:N04-75-1-B-B-26-1-1 X LH244	34.9	9.41	0.0	
18	BR52051:N04-75-1-B-B-26-1-1 X LH332	37.3	9.54	0.0	
19	BR52051:N04-76-1-B-B-10-1-1 X LH244	40.7	8.58	0.0	*
20	BR52051:N04-76-1-B-B-10-1-1 X LH332	43.2	9.77	0.0	*
21	BR52051:N04-76-1-B-B-10-1-2 X LH244	40.3	9.11	0.2	
22	BR52051:N04-76-1-B-B-10-1-2 X LH332	42.2	9.51	0.5	
23	BR52051:N04-76-1-B-B-11-1-1 X LH244	40.5	10.26	1.8	
24	BR52051:N04-76-1-B-B-17-1-1 X LH244	41.3	9.85	0.4	*
25	BR52051:N04-76-1-B-B-17-1-1 X LH332	38.1	10.38	0.5	*
26	BR52051:N04-76-1-B-B-17-1-2 X LH244	40.3	8.16	2.8	
27	BR52051:N04-76-1-B-B-17-1-2 X LH332	44.1	9.97	1.2	
28	BR52051:N04-76-1-B-B-22-1 X LH244	39.1	9.98	0.5	*
29	SCRO1:N1310-398-1-B-21-1-1-B-B X LH244	39.9	10.90	2.7	*
30	SCRO1:N1310-398-1-B-21-1-2-B-B X LH244	37.9	9.68	1.0	*
31	SCRO1:N1310-398-1-B-21-1-3-B-B X LH244	35.3	9.82	0.5	*
32	SCRO1:N1310-398-1-B-21-2-1-B-B X LH244	37.0	11.03	0.0	*
33	SCRO1:N1310-398-1-B-21-1-1-B-B X LH332	39.0	11.20	0.1	*
34	SCRO1:N1310-398-1-B-21-1-2-B-B X LH332	39.1	11.32	0.3	*
35	SCRO1:N1310-398-1-B-21-1-3-B-B X LH332	38.7	10.21	0.5	*
36	SCRO1:N1310-398-1-B-21-2-1-B-B X LH332	39.5	9.93	0.8	*
37	CHO5015:N15-8-1-B-B-22-1-1 X LH227	46.0	9.81	0.0	*
38	CHO5015:N15-8-1-B-B-22-1-1 X LH244	38.0	10.13	0.0	*
39	CHO5015:N15-8-1-B-B-22-1-1 X LH332	38.7	10.11	0.1	*
40	W604S X LH244	40.9	6.91	3.8	*
41	W605S X LH244	37.4	7.41	5.4	*
42	W604S X LH332	41.3	8.10	2.7	*

43	W605S X LH332	38.9	9.89	1.7	*
44	F2F633 (bm3)	32.2	7.91	0.5	*
45	34A20	39.3	8.55	3.0	*
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	Mean	38.6	9.62	0.8	
	CV (%)	6	9	170	
	LSD (0.05)	4.0	1.53	2.4	
	Mean of all experimental entries	38.6	9.84	0.4	
	Mean of experimental entries (30) for quality evaluation	38.6	9.97	0.4	
	Mean of checks (w/o F2633)	39.6	8.17	3.3	

Table 2. Forage yield evaluation for CUBA164 trial in 2007. Forage yield and lodging scores (0 = no lodging) were evaluated at Madison and Arlington, WI. Entries marked with “\*” will be analyzed for nutritional quality.

07No.	Entry	Mean			Quality Evaluation
		Dry matter	Yield	Lodge score	
		%	t/a	0-10	
1	CHIS775:S1911b-645-1-B-B-14-1-1 X LH279	34.5	8.78	0.5	*
2	CHIS775:S1911b-645-1-B-B-14-1-1 X LH287	33.5	8.53	0.2	*
3	CUBA164:S2012-235-1-B-12-1-1 X LH279	34.0	9.36	0.0	*
4	CUBA164:S2012-235-1-B-12-1-1 X LH287	31.6	8.65	0.0	*
5	CUBA164:S2012-235-1-B-12-1-2 X LH279	33.3	9.55	0.0	*
6	CUBA164:S2012-235-1-B-12-1-2 X LH287	31.2	8.90	0.0	*
7	CUBA164:S2012-235-1-B-17-1 X LH279	34.9	9.58	1.5	
8	CUBA164:S2012-235-1-B-17-1 X LH287	32.8	7.50	0.1	
9	CUBA164:S2012-235-1-B-17-1 X W604S	34.7	7.53	0.2	
10	CUBA164:S2012-235-1-B-21-1 X LH279	34.9	9.48	0.0	*
11	CUBA164:S2012-235-1-B-21-1 X LH287	33.9	8.32	0.0	*
12	CUBA164:S2012-235-1-B-4-1-1 X LH279	34.7	9.93	0.0	*
14	CUBA164:S2012-459-1-B-3-1-1 X LH279	40.2	7.93	0.2	
15	CUBA164:S2012-459-1-B-3-1-1 X LH287	32.1	8.13	0.0	
16	CUBA164:S2012-459-1-B-3-1-2 X LH279	40.4	7.50	0.0	
17	CUBA164:S2012-459-1-B-3-1-2 X LH287	34.3	6.88	0.0	
18	CUBA164:S2012-459-1-B-3-1-2 X W604S	32.3	3.89	0.7	
19	CUBA164:S2012-966-1-B-2-1-1 X LH279	37.8	9.59	0.0	*
20	CUBA164:S2012-966-1-B-2-1-1 X LH287	34.8	9.74	0.2	*
21	CUBA164:S2012-966-1-B-2-1-1 X W604S	35.6	7.55	0.4	*
22	CUBA164:S2012-966-1-B-2-1-2 X LH279	37.2	9.70	0.0	*
23	CUBA164:S2012-966-1-B-2-1-2 X LH287	38.6	8.89	0.2	*
24	CUBA164:S2012-966-1-B-2-1-2 X W604S	36.7	6.90	0.8	*
25	W604S X LH244	38.8	6.97	2.2	*
26	W605S X LH244	34.6	9.98	0.7	*
27	W604S X LH332	38.4	7.25	2.8	*
28	W605S X LH332	32.4	10.20	0.2	*
29	F2F633 (bm3)	28.1	7.74	0.0	*
30	Pioneer 34A89	35.4	9.88	1.0	*
Mean		34.9	8.44	0.4	
CV (%)		6	13	261	
LSD (0.05)		2.5	1.24	1.2	
Mean of all CUBA164 testcrosses		35.0	8.38	0.2	
Mean of experimental entries (15) for quality evaluation		34.8	8.93	0.2	
Mean of checks (w/o F2633)		35.9	8.86	1.4	

Table 3. Forage yield evaluation for GEM244 trial in 2007. Forage yield and lodging scores (0 = no lodging) were evaluated at Madison and Arlington, WI. Entries marked with “\*” will be analyzed for nutritional quality.

07No.	Entry	Mean			Quality Evaluation
		Dry matter	Yield	Lodge score	
		%	t/a	0-10	
1	AR17056:N2025-508-1-B-B-B-B-1 X LH244	33.0	8.5	1.7	
2	AR17056:N2025-508-1-B-B-B-B-2 X LH244	31.9	9.3	2.5	
3	AR17056:N2025-508-1-B-B-B-B-5 X LH244	32.5	9.9	0.0	*
4	AR17056:N2025-508-1-B-B-B-B-8 X LH244	32.2	9.2	0.3	
5	AR17056:N2025-508-1-B-B-B-B-9 X LH244	32.4	9.6	2.8	
6	AR17056:N2025-508-1-B-B-B-B-15 X LH244	32.3	9.6	0.3	*
7	AR17056:N2025-508-1-B-B-B-B-16 X LH244	33.2	9.6	2.0	
8	AR17056:N2025-508-1-B-B-B-B-17 X LH244	35.5	8.8	2.7	
9	AR17056:N2025-508-1-B-B-B-B-18 X LH244	32.9	9.6	0.5	
10	DK212T:N11a12-122-1-B-B-2 X LH244	37.9	9.8	1.3	
11	DK212T:N11a12-122-1-B-B-3 X LH244	38.2	10.5	1.3	*
12	DK212T:N11a12-122-1-B-B-5 X LH244	36.9	9.3	0.7	*
13	DK212T:N11a12-122-1-B-B-7 X LH244	40.0	9.3	2.2	
14	DK212T:N11a12-122-1-B-B-8 X LH244	45.1	10.0	1.8	
15	DK212T:N11a12-122-1-B-B-9 X LH244	45.8	9.5	0.0	*
16	DK212T:N11a12-122-1-B-B-13 X LH244	35.7	11.0	1.4	*
17	DK212T:N11a12-122-1-B-B-16 X LH244	37.1	9.0	0.4	
18	DK212T:N11a12-122-1-B-B-19 X LH244	40.2	10.0	0.8	*
19	DK212T:N11a12-122-1-B-B-21 X LH244	38.9	9.7	0.0	*
20	DK212T:N11a12-122-1-B-B-22 X LH244	39.3	10.0	0.2	*
21	FS8B(T):N11a-322-1-B-B-2 X LH244	36.8	11.0	2.0	
22	FS8B(T):N11a-322-1-B-B-3 X LH244	35.6	9.9	0.0	*
23	FS8B(T):N11a-322-1-B-B-4 X LH244	38.0	10.7	0.8	*
24	FS8B(T):N11a-322-1-B-B-5 X LH244	36.4	11.4	1.2	*
25	FS8B(T):N11a-322-1-B-B-6 X LH244	37.0	10.6	2.3	
26	FS8B(T):N11a-322-1-B-B-7 X LH244	35.6	9.7	2.5	
27	FS8B(T):N11a-322-1-B-B-10 X LH244	37.5	10.0	1.2	*
28	FS8B(T):N11a-322-1-B-B-11 X LH244	38.2	8.7	2.2	
29	FS8B(T):N11a-322-1-B-B-13 X LH244	39.3	10.4	1.2	*
30	FS8B(T):N11a-322-1-B-B-14 X LH244	35.6	9.8	0.5	*
31	FS8B(T):N11a-322-1-B-B-15 X LH244	36.3	11.7	0.5	*
32	FS8B(T):N11a-322-1-B-B-16 X LH244	35.8	10.0	1.7	
33	FS8B(T):N11a-322-1-B-B-17 X LH244	38.8	9.9	1.2	
34	FS8B(T):N11a-322-1-B-B-19 X LH244	38.2	11.2	0.0	*
35	SCRO1:N1310-398-1-B-21-1-1-B-B X LH244	39.7	10.2	0.0	*
36	SCRO1:N1310-398-1-B-21-1-2-B-B X LH244	39.0	9.1	1.8	*
37	SCRO1:N1310-398-1-B-21-1-3-B-B X LH244	36.8	10.9	1.3	*
38	SCRO1:N1310-398-1-B-21-2-1-B-B X LH244	36.2	10.6	0.0	*
39	CHO5015:N15-8-1-B-B-22-1-1 X LH244	37.3	10.6	0.0	*
40	W604S X LH244	40.8	7.0	3.8	*
41	W605S X LH244	37.3	9.9	2.7	*
42	W604S X LH332	40.3	8.8	2.7	*

43	W605S X LH332	37.0	8.6	3.3	*
44	F2F633	32.3	7.5	0.7	*
45	34A20	41.5	10.8	1.3	*
Mean		37.1	9.81	1.3	
CV (%)		6.10	12.79	130.6	
LSD (0.05)		3.4	1.86	2.95	
Mean of all GEM244 testcrosses		36.9	9.97	1.1	
Mean of experimental entries (22) for quality evaluation		37.5	10.28	0.6	
Mean of checks (w/o F2633)		39.4	9.03	2.8	

**Reference:**

- USDA - United States Department of Agriculture. National Agricultural Statistics Service. 2007. Crop Production 2007 Summary. (<http://usda.mannlib.cornell.edu/usda/nass/CropProd//2000s/2007/CropProd-02-09-2007.pdf>).
- WASS - Wisconsin Agricultural Statistics Services. 2006. ([http://www.nass.usda.gov/Statistics\\_by\\_State/Wisconsin/Publications/Annual\\_Statistical\\_Bulletin/page20-21.pdf](http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Annual_Statistical_Bulletin/page20-21.pdf)).